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Date: November 2, 2009

To: Alice Yeh (USEPA)
Elizabeth Buckrucker (USACE)

Copy: Bruce Fidler (Louis Berger, Inc.)
Ed Garvey (Louis Berger, Inc.)

From: Solomon Gbondo-Tugbawa (Louis Berger, Inc.)

Re: Summary of Observations – Maps of Erosion (minimum 6 and 12 inches) and Deposition in the Lower Passaic River
Lower Passaic River Restoration Project
W912DQ-08-D-0017, Task Order 0006

Conditional simulation was used to estimate the probability of erosion within the lower Passaic River (River Miles 0-8) based on a series of comparisons of bathymetric surveys. To aid in visualizing these results, maps were produced, showing places where there is a 70% probability of exceeding several erosion thresholds (*e.g.*, any erosion, at least 3 inches of erosion, at least 6 inches of erosion, at least 12 inches of erosion). The selection of a 70% probability threshold represents a very generous criterion by identifying an area as erosional only if there are more than 7 out of 10 chances that it will be so. Conversely, an area is identified as non-erosive (*i.e.*, stable), if it has less than a 1 in 3 chance of actually being stable.

The 70% probability threshold is higher than is typical of USEPA's approaches on other sites, and there is important precedent for use of much lower thresholds. For example:

1. 50% and 40% probability thresholds, respectively, were implemented at the Fox River (Kern *et al.*, 2008) and Hudson River (Kern, 2005) Superfund sites to delineate PCB contamination.

2. For the Pizza Road dioxin site, a USEPA Superfund site in Missouri, Saito and Goovaerts (2002) developed a critical probability threshold of 65% for remediation.

In addition, Barabas *et al.*, (2001) previously estimated a critical probability threshold of 54% for 2,3,7,8-TCDD contamination in the lower Passaic River at a concentration level of 10 ppt. Generally speaking, USEPA guidance (1989, pg. 2-3) argues that a Superfund Site is to be assumed not to have attained cleanup standards (*i.e.*, in this case that contaminated sediments are unstable) unless "substantial evidence" shows otherwise at a high level of confidence.

Based on these observations from other Superfund sites, USEPA guidance and the bathymetric evidence that most areas in the Lower Passaic River have been subject to meaningful erosion events, it is possible that the 70% probability criterion used in depicting erosion represents an approach that may not be viewed by some stakeholders as protective. Thus, the resulting identified portion of the riverbed is best viewed as representing the minimum justifiable area to be addressed. Even so, this assumption covers nearly the entire river bottom in RM0-8.

An “optimal” probability threshold can be selected based on costs associated with false positive and false negative errors in delineating contaminant distributions. Equally weighted costs correspond to a 50% probability threshold and the 70% probability discussed here implies that false negative errors (failure to remediate unstable sediments) are less important than false positive errors (remediating stable sediments). Again, the 70% probability used here may be viewed as un-protective, except that it still results in nearly the entire river bottom in RM0-8 being identified as unstable.

In this memo, bathymetric conditional simulation results were post-processed to prepare maps of erosion and deposition for the Lower Passaic River. The maps for erosion show the areas with at least one occurrence of a 6-inch erosional event with a greater than or equal to 70 percent probability of occurrence (Figure 1a-e). Figure 2a-e shows the areas subject to at least one12-inch erosional event at a similar level of probability. Each erosion map shows two demarcated areas: (i) areas with at least 1 erosion occurrence over all 36 possible combinations of surveys performed between 1989 and 2007 (underlying layer shown in red) and (ii) areas with at least 1 erosion occurrence over the eight sequential survey pairs only (1989-1995; 1996-1996; 1997-1997; 1997-1999; 1999-2001; 2001-2002; 2002-2004; 2004-2007), shown as hatched areas in green (6 in) or blue (12 in).

For the deposition mapping analysis, the objective was to depict the frequency of significant deposition observations and long-term sediment accumulation in areas that have not been subject to any significant erosional events in the past based on the available surveys. A significant depositional observation is defined as having at least 70 percent probability of any deposition. Figure 3a-e displays the frequency of significant deposition in areas that have not been subject to any significant erosion in the past, when considering all 36 possible survey pairs (*i.e.*, in non-significant erosional areas). In this map, frequency of observation is not the same as the number of actual depositional events since there may be multiple observations of the same depositional event. Similarly, Figure 4a-e displays the frequency of significant deposition in areas that have not been subject to any significant erosion in the past when only sequential survey pairs are compared. This figure can be considered to represent the minimum number of depositional events since longer term changes are not captured by these comparisons. Figure 5 shows the long-term elevation changes (1989 - 2007) in areas that have not been subject to any significant erosion in the past based on the 36 possible survey combinations.

Summary of Observations

- Significant observations of erosion of 12 inches or more occurs mostly on the outside of the curves along the river (Figures 2). This area is about 30 percent of the total area simulated when all 36 survey pairs are considered and about 17 percent for sequential pairs.

- The footprint of at least one 6-inches erosional event is more widespread and generally extends from the channel center line to the edges on the outside of curves along the river (Figure 1). The area under this scenario is about 54 percent of the total simulated area, when all 36 survey pairs are considered. When only sequential pairs are considered, the area subject to at least one 6-inch erosional event is about 40 percent of the total area simulated.

- The erosional areas depicted in Figures 1 and 2 likely represent minimum areas, since the bathymetric surveys are unlikely to have been frequent enough to capture all such events.

- Areas without observable erosion are generally limited to below RM 5 in areas on the inside of the curves along the river (Figure 3 and 4). However, these areas are not consistently depositional at 70 percent or more probability, since the frequencies of deposition are typically less than the total number of survey comparisons. That is, these areas do not always accumulate sediment between surveys but have not been observed to erode.

- Areas without observable erosion represent only 20 percent of the area simulated.

- In areas without observable erosion, the highest long-term sediment accumulation rates (more than 4 feet over the 18 year period or >2.7 in/yr) occurs in small patches around RM 2 and below.

- Overall, these maps suggest that significant erosion is widespread in the river with more than half of the area having undergone at least one 6-inch sediment erosion bed change over the past 18 years. While deposition observations have occurred, no significant areas can be delineated where deposition has been consistent over time.

References

Barabas, N., Goovaerts, P., and P. Adriaens. 2004. Modified polytopic vector analysis to identify and quantify a dioxin dechlorination signature in sediments. 2. Application to the Passaic River. Environmental Science & Technology, 38(6), 1821-1827.

Kern, J.W. 2005. Relationship between dredge area footprint and probability of excedence for Tri+ PCBs 10 mg/kg action limits. March 9, 2005 presentation to the Acting Regional Deputy administrator, USEPA Region 2.

Kern, J.W., J. Wolfe and N. Barabas. 2008. Evaluation of increased sampling density for refinement of 30 percent dredge prism design in Upper OU-3. Fox River PCBs Superfund Site. Technical working group memorandum. 28 pp.

Saito, H. and P. Goovaerts, 2002, Accounting for Measurement Error in Uncertainty Modeling and Decision Making using Indicator Kriging and p-field Simulation: Application to a Dioxin Contaminated Site. Environmetrics, 13(5-6): 555-567.

USEPA. 1989. Methods for evaluating the attainment of cleanup standards. Volume 1: Soils and Solid Media. United States Environmental Protection Agency. Office of Policy, Planning and Evaluation. Washington, DC 20460. EPA230/02-89-042.

N

7

0 250 500 1,000 Feet

Legend

Area Subject to Erosion
(At least one 6-in. erosion event at a minimum 70% confidence level)

All Possible Survey Pair Comparisons

Sequential Survey Pair Comparisons

Simulation Grid Extent

Shoreline as defined by the NJDEP

US Army Corps of Engineers®

Conditional Simulation Results
Showing Areas Subject to 6 inches of Erosion at a Minimum 70% Level of Confidence

Lower Passaic River Restoration

Figure 1a

2009

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N

6

5

4

0 250 500 1,000 Feet

Legend

Area Subject to Erosion
(At least one 6-in. erosion event at a minimum 70% confidence level)

All Possible Survey Pair Comparisons

Sequential Survey Pair Comparisons

Simulation Grid Extent

Shoreline as defined by the NJDEP

US Army Corps of Engineers®

Conditional Simulation Results
Showing Areas Subject to 6 inches of Erosion at a Minimum 70% Level of Confidence

Lower Passaic River Restoration

Figure 1b

2009

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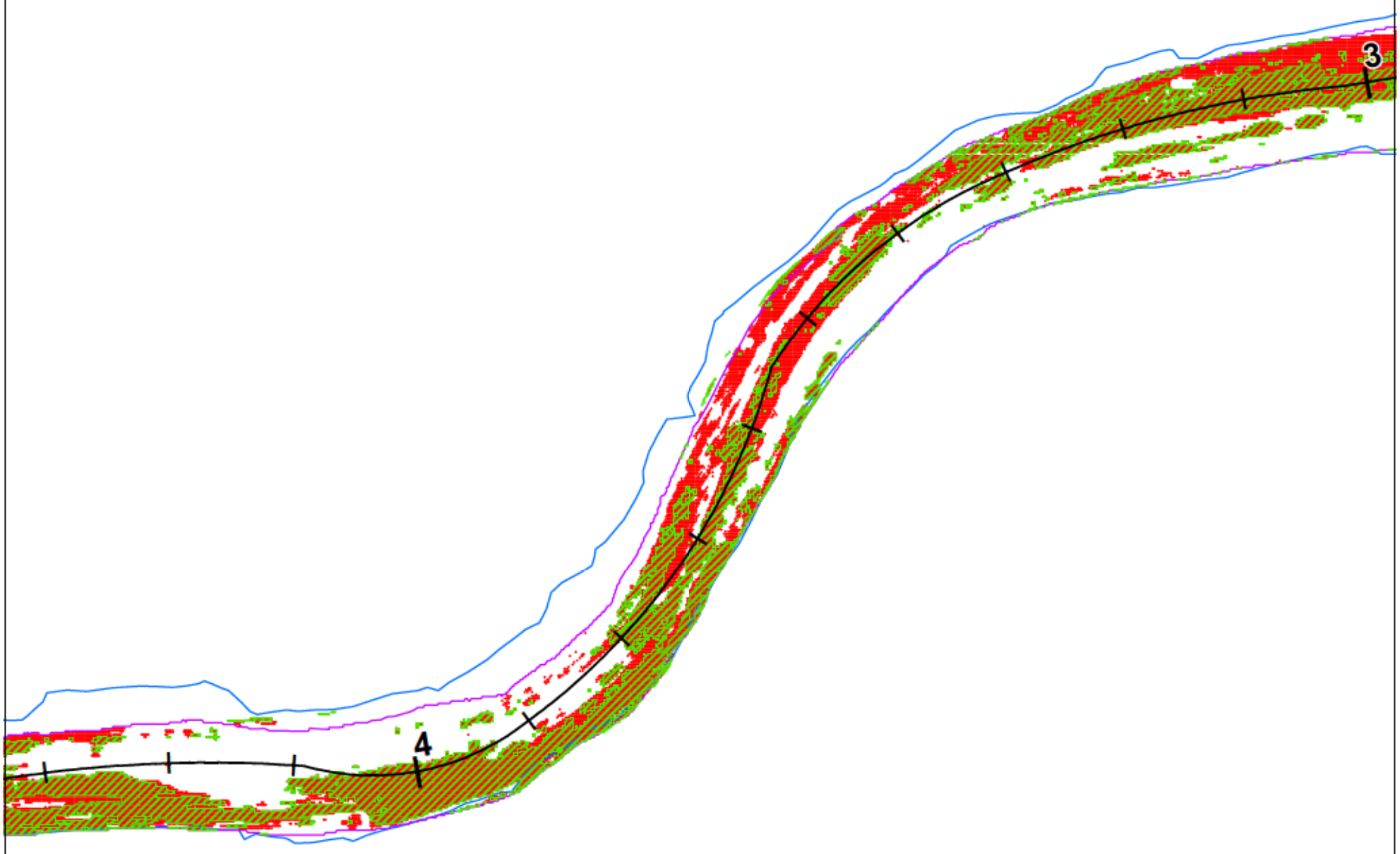
N



0 250 500 1,000 Feet

Legend

Area Subject to Erosion
(At least one 6-in. erosion event at a minimum 70% confidence level)

All Possible Survey Pair Comparisons

Sequential Survey Pair Comparisons

Simulation Grid Extent

Shoreline as defined by the NJDEP

US Army Corps of Engineers®

Conditional Simulation Results
Showing Areas Subject to 6 inches of Erosion at a Minimum 70% Level of Confidence

Lower Passaic River Restoration

Figure 1c

2009

P:\0285924Mapping\CSM_MassBalance\bathymetry_frequency_depth_map_wbookmark_v4.mxd

N

3

2

0 250 500 1,000
Feet

Legend

Area Subject to Erosion
(At least one 6-in. erosion event at a minimum 70% confidence level)

All Possible Survey Pair Comparisons

Sequential Survey Pair Comparisons

Simulation Grid Extent

Shoreline as defined by the NJDEP

US Army Corps of Engineers®

Conditional Simulation Results
Showing Areas Subject to 6 inches of Erosion at a Minimum 70% Level of Confidence

Lower Passaic River Restoration

Figure 1d

2009

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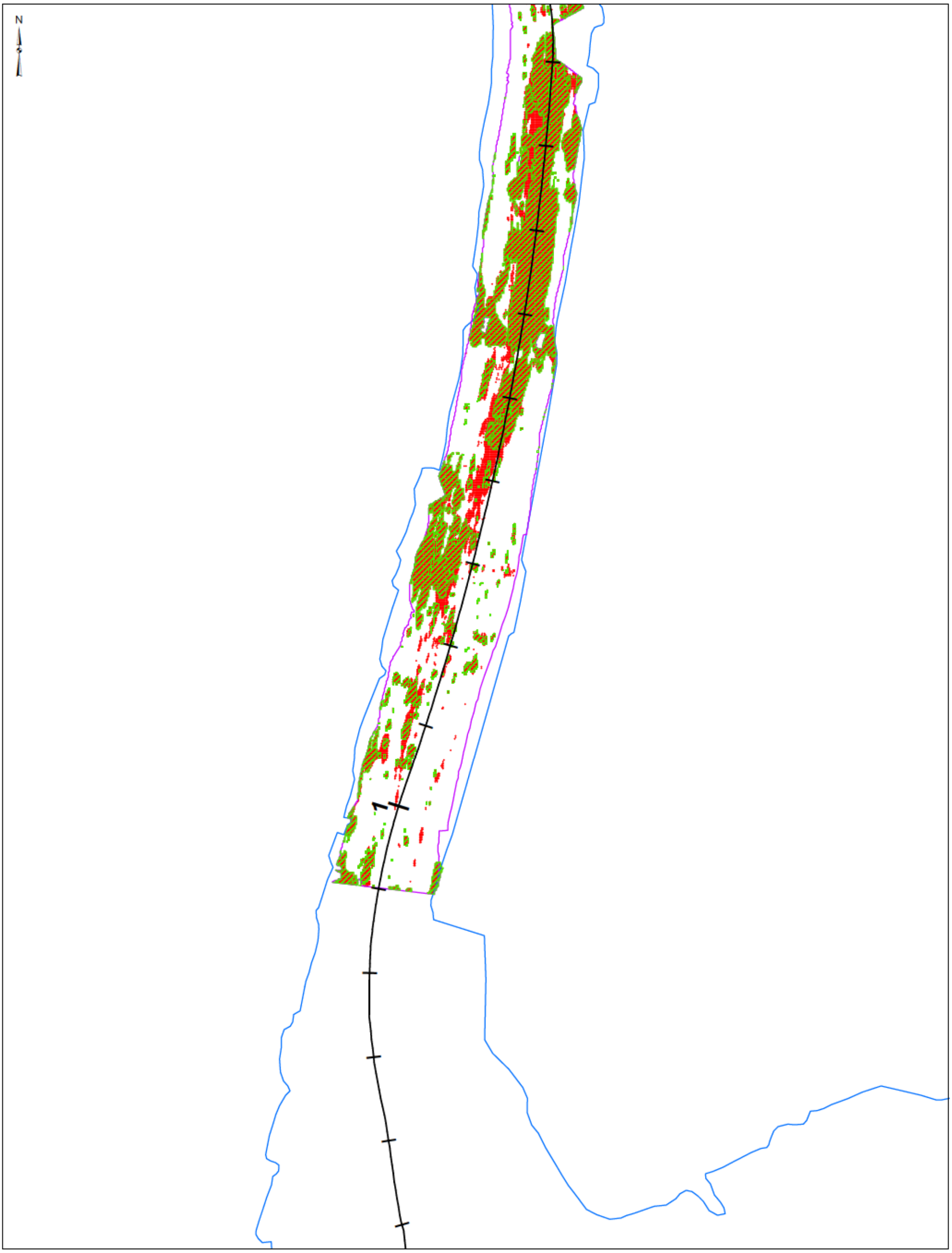

Legend

Area Subject to Erosion
(At least one 6-in. erosion event at a minimum 70% confidence level)

All Possible Survey Pair Comparisons

Sequential Survey Pair Comparisons

Simulation Grid Extent

Shoreline as defined by the NJDEP

Conditional Simulation Results
Showing Areas Subject to 6 inches of Erosion at
a Minimum 70% Level of Confidence

Lower Passaic River Restoration

Figure 1e

2009

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Legend

Area Subject to Erosion
(At least one 12-in. erosion event at a minimum 70% confidence level)

All Possible Survey Pair Comparisons

Sequential Survey Pair Comparison

Simulation Grid Extent

Shoreline as defined by the NJDEP

US Army Corps of Engineers®

Conditional Simulation Results
Showing Areas Subject to 12 inches of Erosion at a Minimum 70% Level of Confidence

Lower Passaic River Restoration

Figure 2a

2009

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N

6

5

4

0 250 500 1,000 Feet

Legend

Area Subject to Erosion
(At least one 12-in. erosion event at a minimum 70% confidence level)

All Possible Survey Pair Comparisons

Sequential Survey Pair Comparison

Simulation Grid Extent

Shoreline as defined by the NJDEP

US Army Corps of Engineers

Conditional Simulation Results
Showing Areas Subject to 12 inches of Erosion at a Minimum 70% Level of Confidence

Lower Passaic River Restoration

Figure 2b

2009

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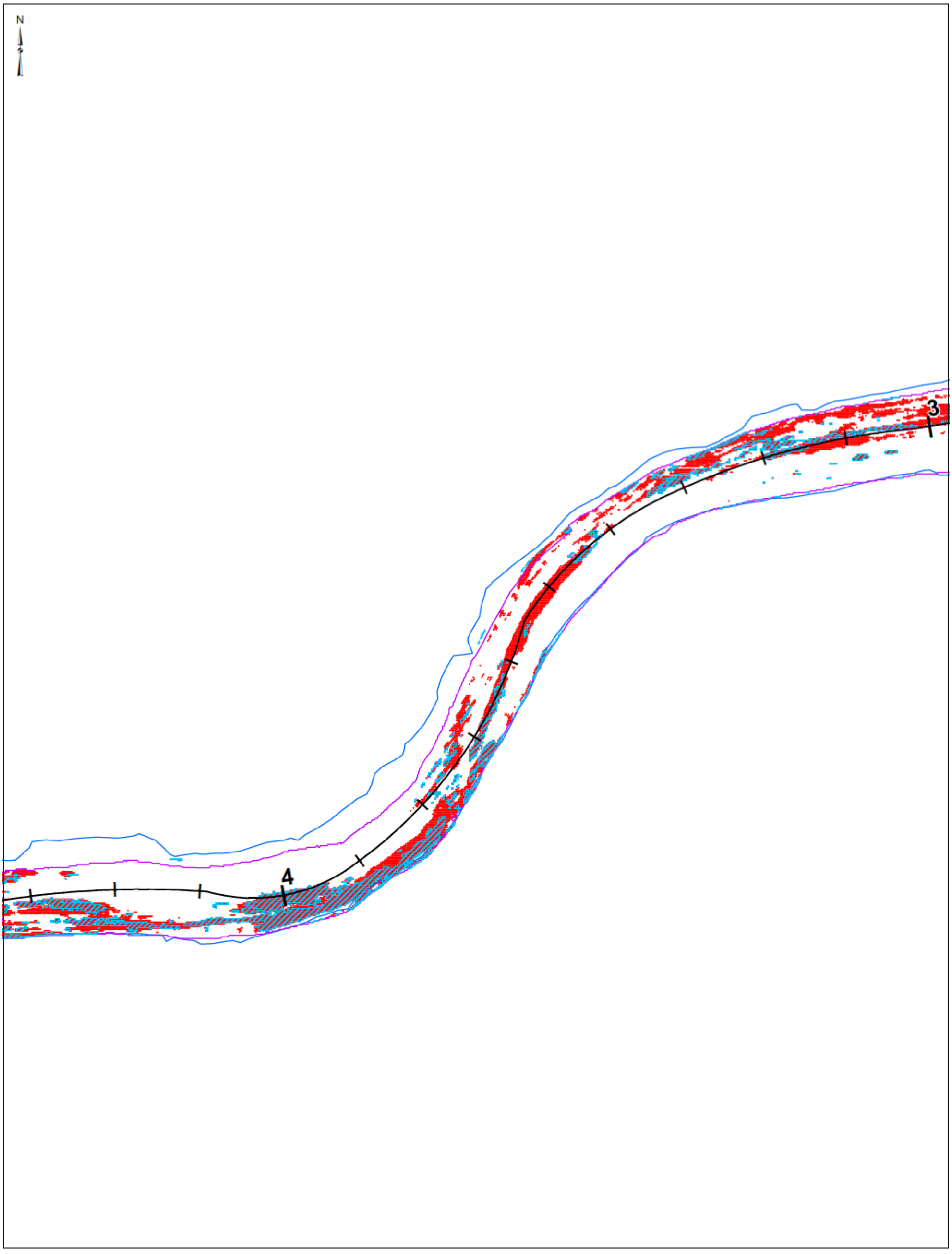

Legend

Area Subject to Erosion
(At least one 12-in. erosion event at a minimum 70% confidence level)

All Possible Survey Pair Comparisons

Sequential Survey Pair Comparison

Simulation Grid Extent

Shoreline as defined by the NJDEP

Conditional Simulation Results
Showing Areas Subject to 12 inches of Erosion at
a Minimum 70% Level of Confidence

Lower Passaic River Restoration

Figure 2c

2009

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N

3

2

0 250 500 1,000
Feet

Legend

Area Subject to Erosion
(At least one 12-in. erosion event at a minimum 70% confidence level)

All Possible Survey Pair Comparisons

Sequential Survey Pair Comparison

Simulation Grid Extent

Shoreline as defined by the NJDEP

US Army Corps of Engineers®

Conditional Simulation Results
Showing Areas Subject to 12 inches of Erosion at a Minimum 70% Level of Confidence

Lower Passaic River Restoration

Figure 2d

2009

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N

1

0 250 500 1,000
Feet

Legend

Area Subject to Erosion
(At least one 12-in. erosion event at a minimum 70% confidence level)

All Possible Survey Pair Comparisons

Sequential Survey Pair Comparison

Simulation Grid Extent

Shoreline as defined by the NJDEP

US Army Corps of Engineers®

Conditional Simulation Results
Showing Areas Subject to 12 inches of Erosion at a Minimum 70% Level of Confidence

Lower Passaic River Restoration

Figure 2e

2009

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0 250 500 1,000 Feet

Legend

Area Subject to Erosion at 70% Confidence Level

Number of Deposition Observations at 70% Confidence Level

1
2 to 8
9 to 15
16 to 22
>= 23

Note: The white areas within the simulation grid extent represents area where no erosional events were observed at a 70% level of confidence.
These areas also had no observations of deposition with a 70% level of confidence.

Simulation Grid Extent

Shoreline as defined by the NJDEP

Conditional Simulation Results for All Possible Survey Pairs Comparison Showing Depositional Observations at a Minimum 70% Level of Confidence in Non-Significant Erosion Areas

Lower Passaic River Restoration

Figure 3-a

2009

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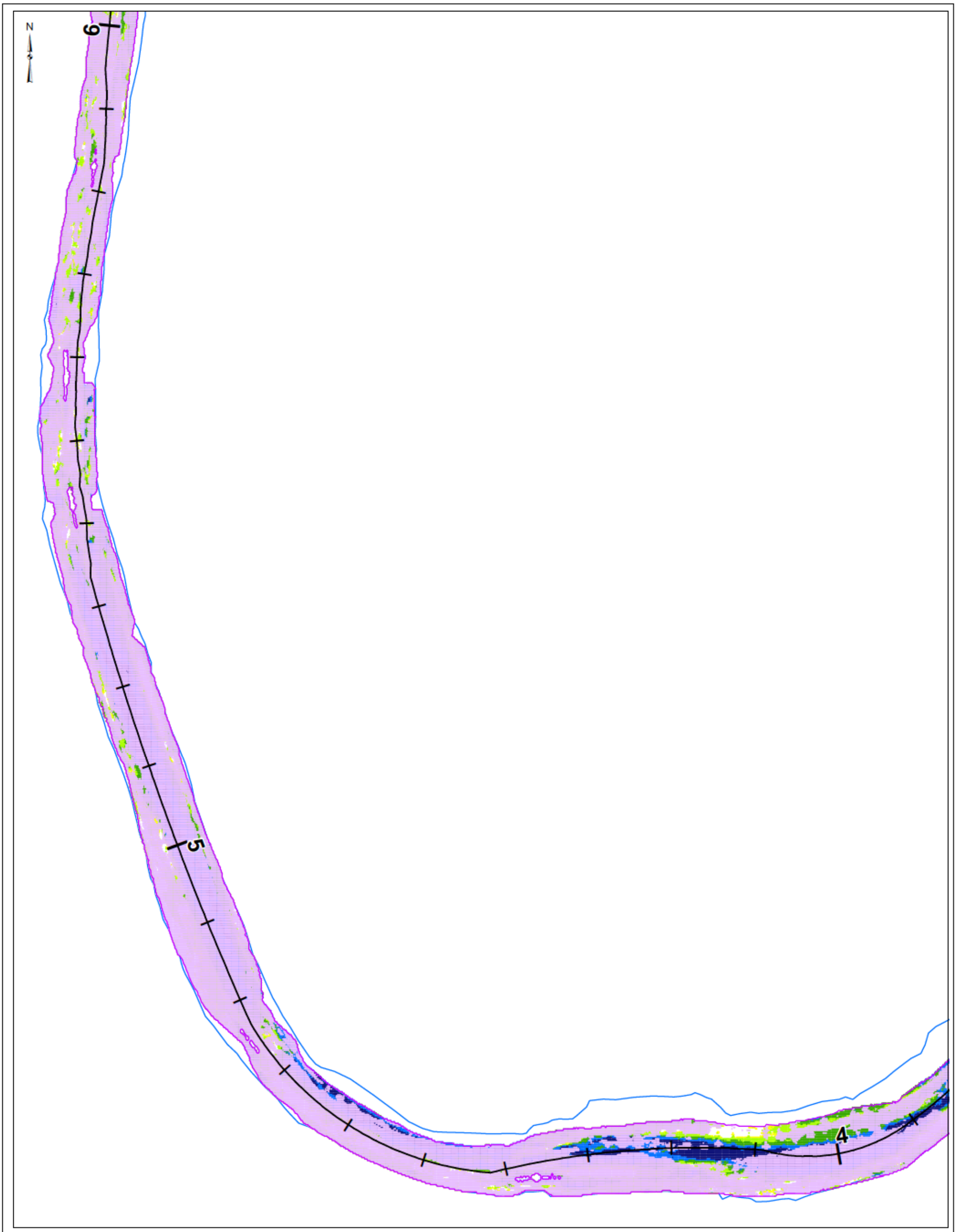

0 250 500 1,000 Feet

Legend

Area Subject to Erosion at 70% Confidence Level

Number of Deposition Observations at 70% Confidence Level

1
2 to 8
9 to 15
16 to 22
>= 23

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Simulation Grid Extent

Shoreline as defined by the NJDEP

Conditional Simulation Results for All Possible Survey Pairs Comparison Showing Depositional Observations at a Minimum 70% Level of Confidence in Non-Significant Erosion Areas

Lower Passaic River Restoration

Figure 3-b

2009

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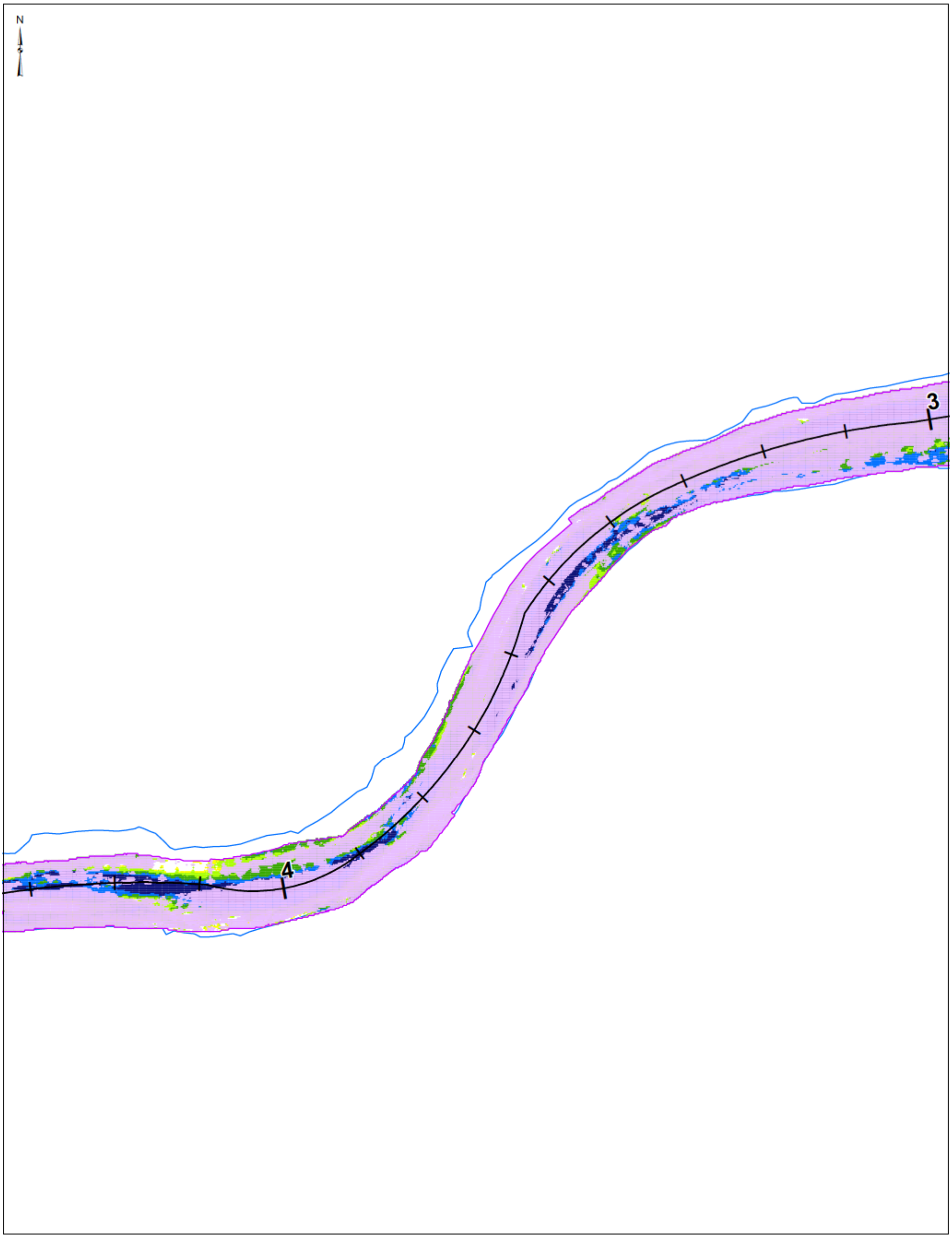

Legend

Area Subject to Erosion at 70% Confidence Level

Number of Deposition Observations at 70% Confidence Level

1
2 to 8
9 to 15
16 to 22
>= 23

0 250 500 1,000 Feet

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Simulation Grid Extent

Shoreline as defined by the NJDEP

Conditional Simulation Results for All Possible Survey Pairs Comparison Showing Depositional Observations at a Minimum 70% Level of Confidence in Non-Significant Erosion Areas

Lower Passaic River Restoration

Figure 3-c

2009

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N

3

2

0 250 500 1,000
Feet

Legend

Area Subject to Erosion at 70% Confidence Level

Number of Deposition Observations at 70% Confidence Level

1

2 to 8

9 to 15

16 to 22

>= 23

Note: The white areas within the simulation grid extent represents area where no erosional events were observed at a 70% level of confidence.
These areas also had no observations of deposition with a 70% level of confidence.

Simulation Grid Extent

Shoreline as defined by the NJDEP

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Conditional Simulation Results for All Possible Survey Pairs Comparison Showing Depositional Observations at a Minimum 70% Level of Confidence in Non-Significant Erosion Areas

Lower Passaic River Restoration

Figure 3-d

2009

N

0 250 500 1,000 Feet

Legend

Area Subject to Erosion at 70% Confidence Level

Number of Deposition Observations at 70% Confidence Level

1

2 to 8

9 to 15

16 to 22

>= 23

Note: The white areas within the simulation grid extent represents area where no erosional events were observed at a 70% level of confidence.
These areas also had no observations of deposition with a 70% level of confidence.

Simulation Grid Extent

Shoreline as defined by the NJDEP

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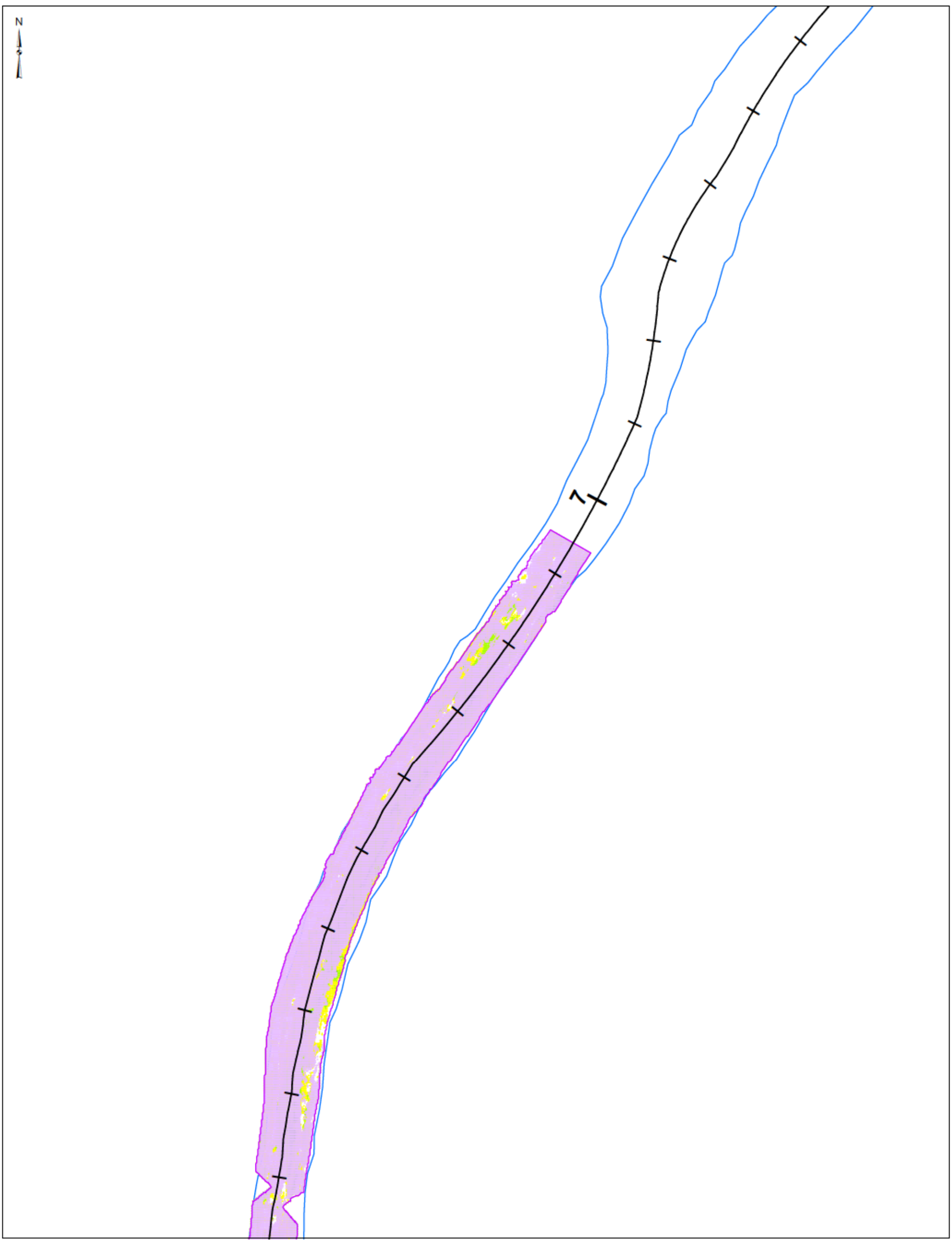
Conditional Simulation Results for All Possible Survey Pairs Comparison Showing Depositional Observations at a Minimum 70% Level of Confidence in Non-Significant Erosion Areas

Lower Passaic River Restoration

Figure 3-e

2009



Legend

Area Subject to Erosion at 70% Confidence Level

Number of Deposition Observations at 70% Confidence Level

1
2 to 8
9 to 15
16 to 22
>= 23

0 250 500 1,000 Feet

Note: The white areas within the simulation grid extent represents area where no erosional events were observed at a 70% level of confidence.
These areas also had no observations of deposition with a 70% level of confidence.

Simulation Grid Extent

Shoreline as defined by the NJDEP

Conditional Simulation Results for Sequential Survey Pairs Comparison Showing Depositional Observations at a Minimum 70% Level of Confidence in Non-Significant Erosion Areas

Lower Passaic River Restoration

Figure 4-a

2009

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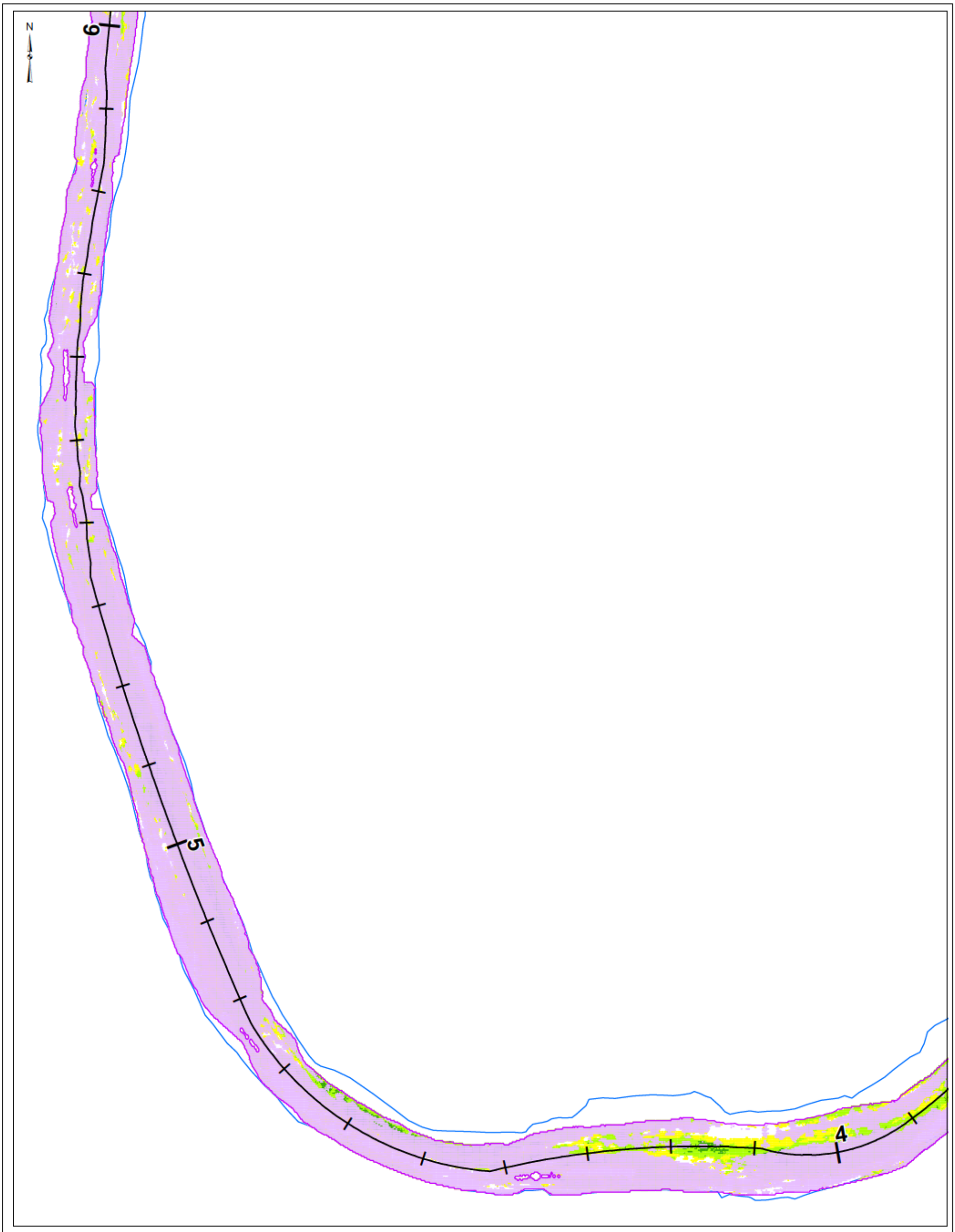

0 250 500 1,000 Feet

Legend

Area Subject to Erosion at 70% Confidence Level

Number of Deposition Observations at 70% Confidence Level

1
2 to 8
9 to 15
16 to 22
>= 23

Note: The white areas within the simulation grid extent represents area where no erosional events were observed at a 70% level of confidence.
These areas also had no observations of deposition with a 70% level of confidence.

Simulation Grid Extent

Shoreline as defined by the NJDEP

Conditional Simulation Results for Sequential Survey Pairs Comparison Showing Depositional Observations at a Minimum 70% Level of Confidence in Non-Significant Erosion Areas

Lower Passaic River Restoration

Figure 4-b

2009

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Legend

0 250 500 1,000 Feet

Area Subject to Erosion at 70% Confidence Level

Number of Deposition Observations at 70% Confidence Level

1
2 to 8
9 to 15
16 to 22
>= 23

Note: The white areas within the simulation grid extent represents area where no erosional events were observed at a 70% level of confidence.
These areas also had no observations of deposition with a 70% level of confidence.

Simulation Grid Extent

Shoreline as defined by the NJDEP

Conditional Simulation Results for Sequential Survey Pairs Comparison Showing Depositional Observations at a Minimum 70% Level of Confidence in Non-Significant Erosion Areas

Lower Passaic River Restoration

Figure 4-c

2009

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N

3

2

0 250 500 1,000
Feet

Legend

Area Subject to Erosion at 70% Confidence Level

Number of Deposition Observations at 70% Confidence Level

1

2 to 8

9 to 15

16 to 22

>= 23

Note: The white areas within the simulation grid extent represents area where no erosional events were observed at a 70% level of confidence.
These areas also had no observations of deposition with a 70% level of confidence.

Simulation Grid Extent

Shoreline as defined by the NJDEP

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Conditional Simulation Results for Sequential Survey Pairs Comparison Showing Depositional Observations at a Minimum 70% Level of Confidence in Non-Significant Erosion Areas

Lower Passaic River Restoration

Figure 4-d

2009

Legend

Area Subject to Erosion at 70% Confidence Level

Number of Deposition Observations at 70% Confidence Level

1
2 to 8
9 to 15
16 to 22
>= 23

Note: The white areas within the simulation grid extent represents area where no erosional events were observed at a 70% level of confidence.
These areas also had no observations of deposition with a 70% level of confidence.

Simulation Grid Extent

Shoreline as defined by the NJDEP

Conditional Simulation Results for Sequential Survey Pairs Comparison Showing Depositional Observations at a Minimum 70% Level of Confidence in Non-Significant Erosion Areas

Lower Passaic River Restoration

Figure 4-e

2009

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N

7

Legend

0 250 500 1,000 Feet

Area Subject to Erosion at 70% Confidence Level

Long Term (1989 to 2007) Elevation Change (ft)

<= 0.5 | 0.5 - 1 | 1 - 2 | 2 - 3 | 3 - 4 | 4 - 5 | 5 - 6 | > 6

Note: The white areas within the simulation grid extent represents area where no erosional events were observed at a 70% level of confidence.
These areas also had no observations of deposition with a 70% level of confidence.

Simulation Grid Extent

Shoreline as defined by the NJDEP

Conditional Simulation Results for All Possible Survey Pairs Comparison Showing Long Term (1989-2007) Elevation Changes in Non-Significant Erosion Areas

Lower Passaic River Restoration

Figure 5-a

2009

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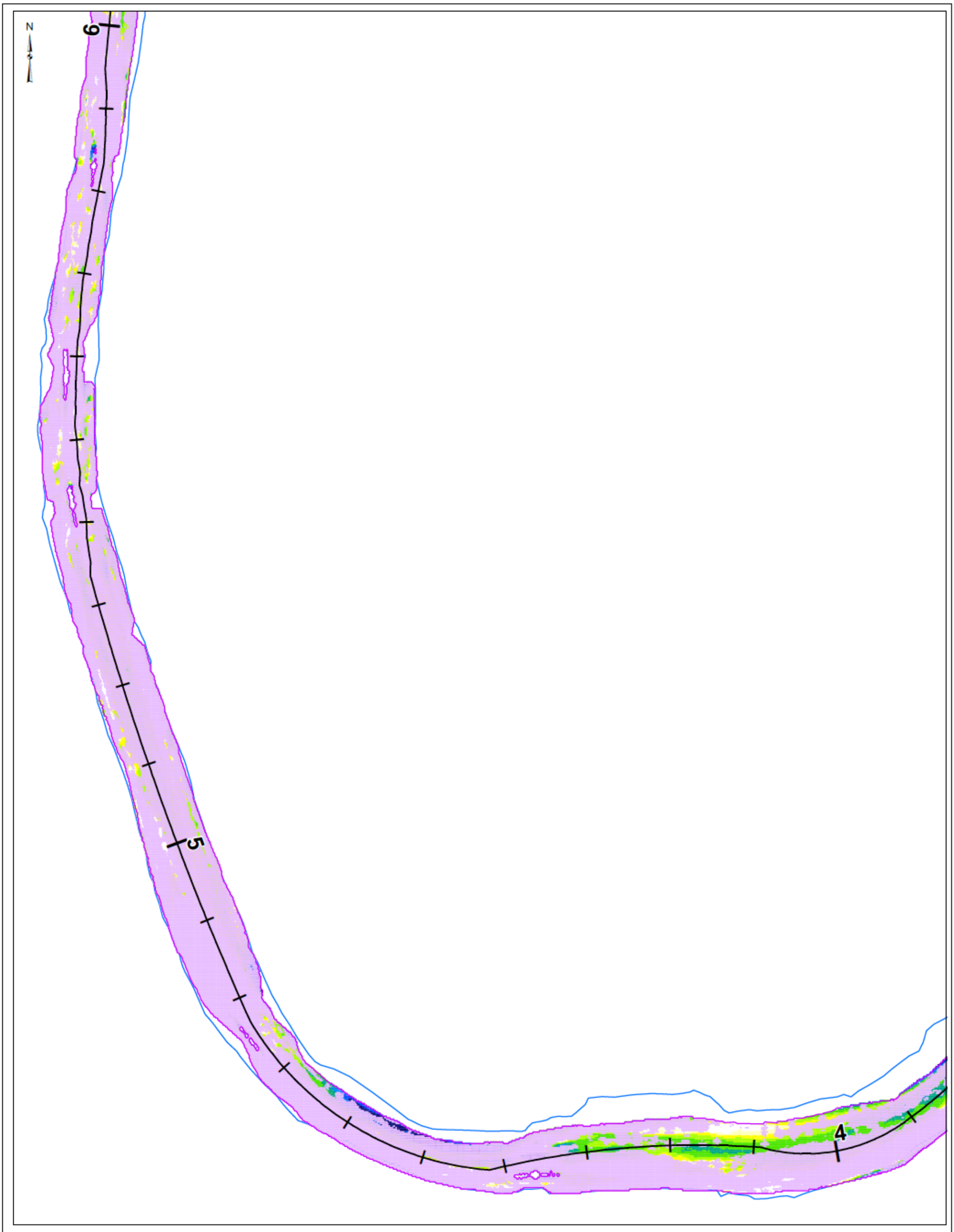

Legend

Area Subject to Erosion at 70% Confidence Level

Long Term (1989 to 2007) Elevation Change (ft)

<= 0.5 | 0.5 - 1 | 1 - 2 | 2 - 3 | 3 - 4 | 4 - 5 | 5 - 6 | > 6

0 250 500 1,000 Feet

Note: The white areas within the simulation grid extent represents area where no erosional events were observed at a 70% level of confidence.
These areas also had no observations of deposition with a 70% level of confidence.

Simulation Grid Extent

Shoreline as defined by the NJDEP

Conditional Simulation Results for All Possible Survey Pairs Comparison Showing Long Term (1989-2007) Elevation Changes in Non-Significant Erosion Areas

Lower Passaic River Restoration

Figure 5-b

2009

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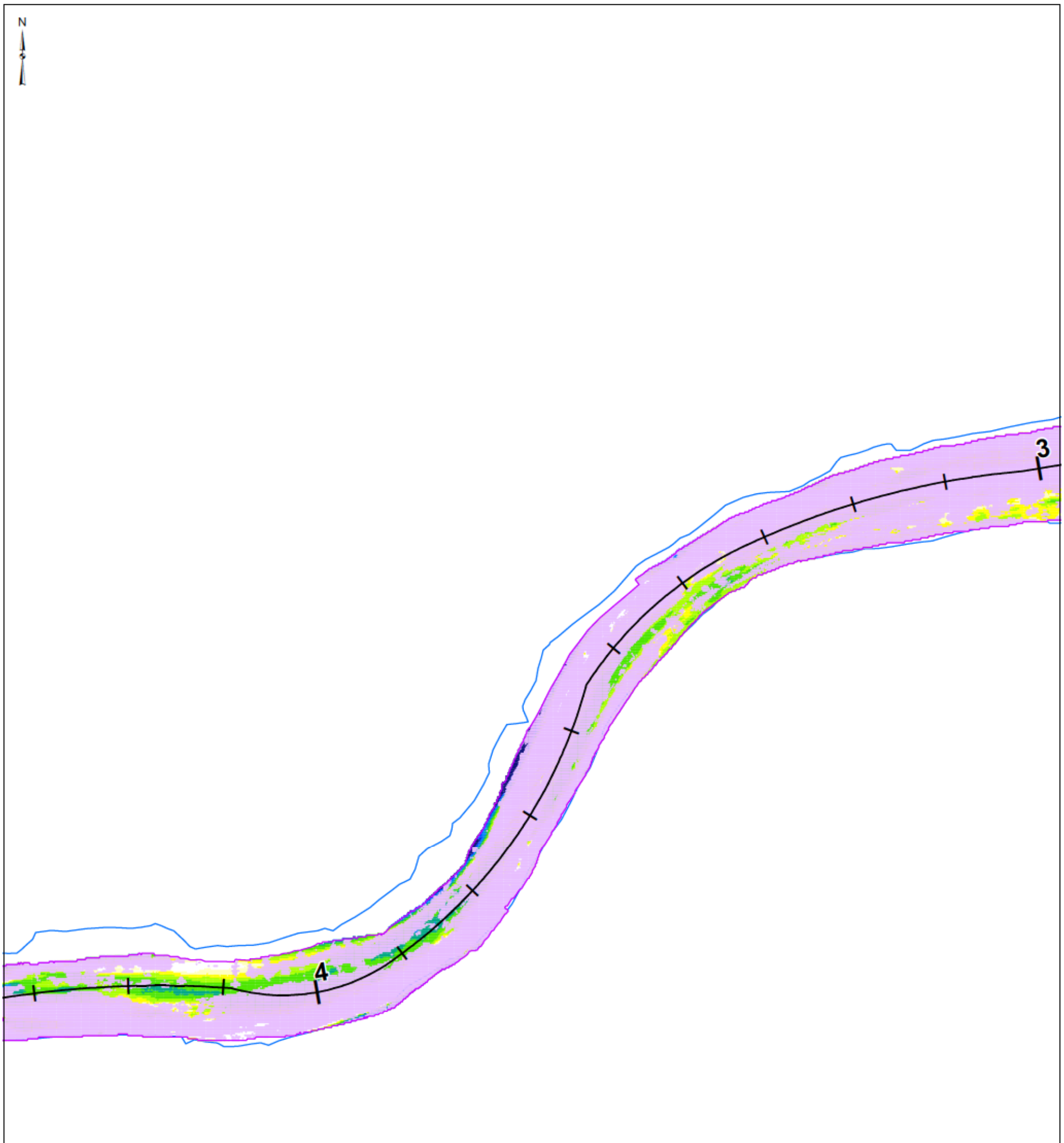

Legend

0 250 500 1,000 Feet

Area Subject to Erosion at 70% Confidence Level

Long Term (1989 to 2007) Elevation Change (ft)

<= 0.5 | 0.5 - 1 | 1 - 2 | 2 - 3 | 3 - 4 | 4 - 5 | 5 - 6 | > 6

Note: The white areas within the simulation grid extent represents area where no erosional events were observed at a 70% level of confidence.
These areas also had no observations of deposition with a 70% level of confidence.

Simulation Grid Extent

Shoreline as defined by the NJDEP

Conditional Simulation Results for All Possible Survey Pairs Comparison Showing Long Term (1989-2007) Elevation Changes in Non-Significant Erosion Areas

Lower Passaic River Restoration

Figure 5-c

2009

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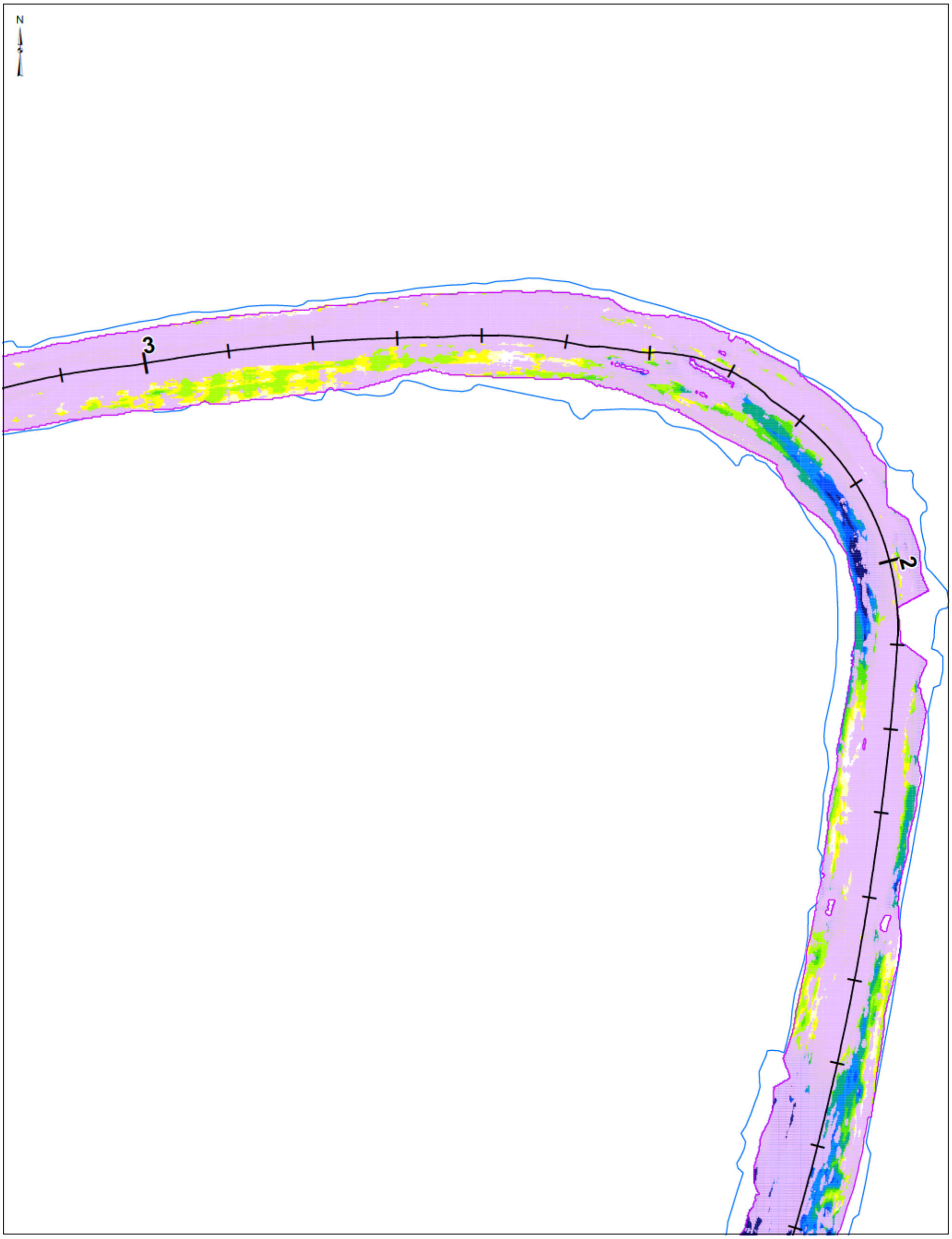

Legend

Area Subject to Erosion at 70% Confidence Level

Long Term (1989 to 2007) Elevation Change (ft)

<= 0.5
0.5 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6

Note: The white areas within the simulation grid extent represents area where no erosional events were observed at a 70% level of confidence.
These areas also had no observations of deposition with a 70% level of confidence.

Simulation Grid Extent

Shoreline as defined by the NJDEP

Conditional Simulation Results for All Possible Survey Pairs Comparison Showing Long Term (1989-2007) Elevation Changes in Non-Significant Erosion Areas

Lower Passaic River Restoration

Figure 5-d

2009

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N

0 250 500 1,000 Feet

Legend

Area Subject to Erosion at 70% Confidence Level

Long Term (1989 to 2007) Elevation Change (ft)

<= 0.5 | 0.5 - 1 | 1 - 2 | 2 - 3 | 3 - 4 | 4 - 5 | 5 - 6 | > 6

Note: The white areas within the simulation grid extent represents area where no erosional events were observed at a 70% level of confidence.
These areas also had no observations of deposition with a 70% level of confidence.

Simulation Grid Extent

Shoreline as defined by the NJDEP

Conditional Simulation Results for All Possible Survey Pairs Comparison Showing Long Term (1989-2007) Elevation Changes in Non-Significant Erosion Areas

Lower Passaic River Restoration

Figure 5-e

2009

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